B-PHYSICS SIGNATURE OF A SUPERSYMMETRIC U(2) FLAVOR MODEL*

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We discuss the B-physics signature of a supersymmetric U(2) flavor model in which the third generation scalars are relatively light (electroweak scale masses). We impose current experimental constraints on such a framework and obtain expectations for various B-physics processes. Here we present CP violation in $B_d \to X_s\gamma$ and $B_d \to \phi K_s$, and, $B_s\bar{B}_s$ mixing. We show that if realized in nature, such a framework can be discovered in current and upcoming experiments.

1. Introduction

The Standard Model (SM) of high energy physics suffers from the gauge hierarchy problem and the flavor problem. Supersymmetry (SUSY) eliminates the gauge hierarchy problem, and a (horizontal) flavor symmetry in generation space could explain the flavor problem. A SUSY theory with a flavor symmetry might relate the quark/lepton flavor structure with that of the scalar quark/lepton sector. Such a theory would imply certain predictions for flavor changing neutral current (FCNC) processes that we wish to investigate in this work, along with the constraints from experimental FCNC data.

We do not assume an alignment of the quark/lepton flavor structure with that of the scalar quark/lepton sector, leading to a non-minimal flavor violation (NMFV) scenario. We consider a spontaneously broken U(2) flavor symmetry [1,2] in the framework of "effective supersymmetry" [3], in which the first two generation scalars are relatively heavy (a few TeV mass),

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thereby satisfying neutron electric dipole moment constraint, etc., while still allowing large CP violating phases in the scalar sector. We analyze the implications of such a framework to B-physics observables. We will present details in a forthcoming paper [4].

Consider that the first and second generation superfields (ψ_a, a=1,2) transform as a U(2) doublet while the third generation superfield (ψ) is a singlet [2]. The most general U(2) symmetric superpotential can be written as

$$W = \psi\alpha_1 H\psi + \frac{\phi^a}{M}\psi\alpha_2 H\psi_a + \frac{\phi^{ab}}{M}\psi_a\alpha_3 H\psi_b + \frac{\phi^a\phi^b}{M^2}\psi_a\alpha_4 H\psi_b + \frac{S^{ab}}{M}\psi_a\alpha_5 H\psi_b + \mu H_u H_d \ , \tag{1}$$

where M is the cutoff scale below which such an effective description is valid, the α_i are O(1) constants, ϕ^a is a U(2) doublet, ϕ^{ab} and S^{ab} are second rank antisymmetric and symmetric U(2) tensors respectively. If U(2) is broken spontaneously by the Vacuum Expectation Values (VEV)

$$\langle\phi^a\rangle = \begin{pmatrix} 0 \\ V \end{pmatrix}; \quad \langle\phi^{ab}\rangle = v\epsilon^{ab}; \quad \langle S^{11,12,21}\rangle = 0, \langle S^{22}\rangle = V,$$

with $\frac{V}{M} \equiv \epsilon \sim 0.02$ and $\frac{v}{M} \equiv \epsilon' \sim 0.004$, and if U(2) is broken below the SUSY breaking scale, the SUSY breaking masses would also have a structure dictated by U(2). The resulting quark and scalar down-type masses are

$$M_d = v_d \begin{pmatrix} O & -\lambda_1\epsilon' & O \\ \lambda_1\epsilon' & \lambda_2\epsilon & \lambda_4\epsilon \\ O & \lambda_4'\epsilon & \lambda_3 \end{pmatrix} \ , \quad M^2_{RL} = v_d \begin{pmatrix} O & -A_1\epsilon' & O \\ A_1\epsilon' & A_2\epsilon & A_4\epsilon \\ O & A_4'\epsilon & A_3 \end{pmatrix} \ , \tag{2}$$

$$M^2_{LL} = \begin{pmatrix} m_1^2 & 0 & 0 \\ 0 & m_1^2+\epsilon^2 m_2^2 & \epsilon m_4^{2*} \\ 0 & \epsilon m_4^2 & m_3^2 \end{pmatrix}_{LL} \ , \quad M^2_{RR} = \begin{pmatrix} m_1^2 & 0 & 0 \\ 0 & m_1^2+\epsilon^2 m_2^2 & \epsilon m_4^{2*} \\ 0 & \epsilon m_4^2 & m_3^2 \end{pmatrix}_{RR} \ ,$$

where $v_d = \langle h_d\rangle$ is the VEV of the Higgs field, the λ_i's are O(1) coefficients, and, m_i and A_i (complex in general) are determined by the SUSY breaking mechanism. It has been shown [2] that such a pattern of the quark mass matrix explains the quark masses and CKM elements.

For our study, we consider the following values for the various SUSY parameters: $m_{\tilde{b}_R,\tilde{t}_R} = 100\,\mathrm{GeV}$, the other squark masses given by $m_0 = 1000\,\mathrm{GeV}$, $A = 1000\,\mathrm{GeV}$, $\tan\beta = 5$, $|\mu| = 150\,\mathrm{GeV}$, $M_2 = 250\,\mathrm{GeV}$, $M_{\tilde{g}} = 250\,\mathrm{GeV}$ and $m_{H^\pm} = 250\,\mathrm{GeV}$. ($m_0$ and A denote generic SUSY breaking mass scales.)

Here, we consider processes that go through the $b \to s$ quark level transition, and in our framework the dominant SUSY contributions are due to $\delta^{RL,RR,LL}_{32,23} \equiv \frac{(M^2_{RL,RR,LL})_{32,23}}{m_0^2}$. For the chosen values of the parameters, we find $|\delta^{RL}_{32,23}| \sim \frac{v_d A \epsilon}{\tilde{m}_0^2} = 6.8 \times 10^{-4}$, and, $|\delta^{LL,RR}_{32}| \sim \epsilon \frac{m_4^2}{m_0^2} = 0.02$.

2. B-physics probes

Given such an effective SUSY theory we estimate the sizes of various B-physics observables that we expect are modified from their SM predictions. In addition to the SM contribution, we include the charged Higgs, chargino and gluino contributions. We analyze the $\Delta B = 1$ FCNC processes, $B_d \to X_s \gamma$, $B_d \to X_s\, g$, $B_d \to X_s \ell^+ \ell^-$, $B_d \to \phi K_s$; and the $\Delta B = 2$ processes $B_s \bar{B}_s$ mixing and the dilepton asymmetry in B_s. We find regions in U(2) SUSY parameter space that are consistent with current experimental data and obtain expectations for measurements that are forthcoming. To illustrate the effects, we present here expectations for CP asymmetries in $B_d \to X_s \gamma$ and $B_d \to \phi K_s$, and, $B_s \bar{B}_s$ mixing. A more exhaustive analysis will be presented elsewhere [4].

The CP asymmetry in $B_d \to X_s \gamma$ is given by

$$A_{CP}^{B_d \to X_s \gamma} \equiv \frac{\Gamma(\bar{B}_d \to X_s \gamma) - \Gamma(B_d \to X_{\bar{s}} \gamma)}{\Gamma(\bar{B}_d \to X_s \gamma) + \Gamma(B_d \to X_{\bar{s}} \gamma)} \ , \tag{3}$$

and the expectation in the U(2) SUSY theory is shown in Fig. (1). We see that significant CP asymmetry is possible in the scenario we are considering, while satisfying experimental constraints.

The CP asymmetry in $B_d \to \phi K_s$ is defined by

$$A_{CP}^{B_d \to \phi K_s} \equiv \frac{\Gamma\left(\bar{B}_d(t) \to \phi K_s\right) - \Gamma\left(B_d(t) \to \phi K_s\right)}{\Gamma\left(\bar{B}_d(t) \to \phi K_s\right) + \Gamma\left(B_d(t) \to \phi K_s\right)} \tag{4}$$

$$= -C_{\phi K} \cos\left(\Delta m_{B_d}\, t\right) + S_{\phi K} \sin\left(\Delta m_{B_d}\, t\right), \tag{5}$$

and Fig. (2 left) shows the CP asymmetry in $B_d \to \phi K_s$ for a scan on δ^{RL}_{32} while satisfying all experimental constraints.

The $B_s \bar{B}_s$ mixing parameter Δm_{B_s} depends quite sensitively on δ^{RR}_{32} and can be significantly altered from the SM prediction as shown in Fig. (2 right).

In conclusion, we note that similar results hold for flavor models that have the same order of magnitude for the 23 element in the squark mass matrix. In such cases, the prospects look exciting for discovering SUSY in B meson processes at current and upcoming colliders.

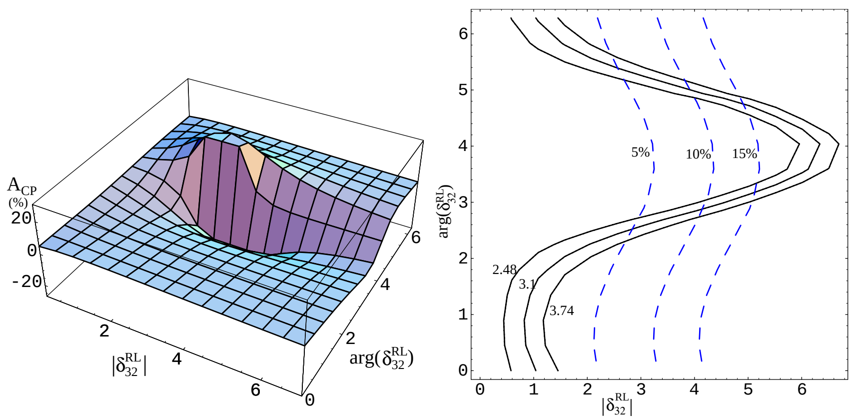

Figure 1. Left: $A_{CP}^{B_d \to X_s \gamma}$(in %) as a function of $|\delta_{32}^{RL}|$(units of 6.8×10^{-4}) and $\arg(\delta_{32}^{RL})$. Right: $1\,\sigma$ contours of B.R.$(B_d \to X_s\gamma)$ (solid lines, in units of $\times 10^{-4}$) and 5 %, 10 % and 15 % contours of B.R.$(B_d \to X_s\, g)$ (dashed lines). The other parameter values are as given in the text and $\arg(\mu) = 5.4$.

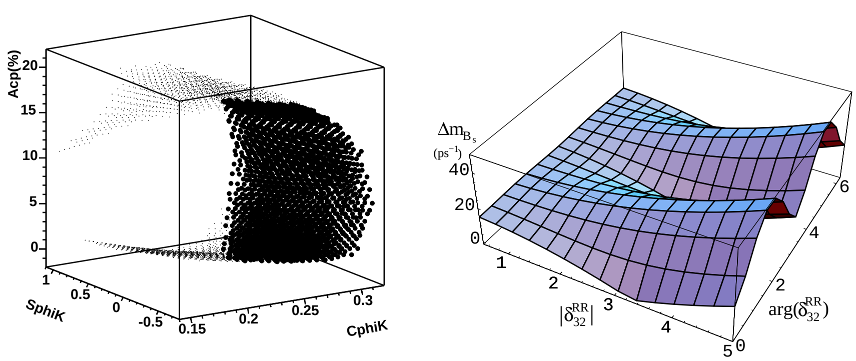

Figure 2. Left: $A_{CP}^{B_d \to X_s \gamma}$, $S_{\phi K}$ and $C_{\phi K}$ for the region of parameter space that satisfy the experimental constraints of B.R.$(B_d \to X_s\gamma)$ and B.R.$(B_d \to \phi K_s)$ (thin and thick dots) and those that also satisfy the current constraints on $S_{\phi K}$ and $C_{\phi K}$ (thick dots). Right: The dependence of Δm_{B_s} (ps^{-1}) on $|\delta_{32}^{RR}|$ (in units of 0.02) and $\arg(\delta_{32}^{RR})$.

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